RESEARCH ARTICLE

Performance of Salt Bridge in Microbial Fuel Cell at Various Agarose Concentrations for Treating Sugar Industrial Effluent

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ABSTRACT: Microbial Fuel Cell (MFC) is a technology that converts chemical energy into electrical energy with catalytic reaction from microorganism. In this study, sugar mill effluent (SME) was used as the anodic substrate in a double chambered MFC for an application of electricity generation. Salt-bridge is the economic alternative to highly priced proton-exchange membrane in the construction of a microbial fuel cell. By altering the concentration of agar in the fabrication of salt-bridge, performance of microbial fuel cells was observed using sugar industrial wastewater as the substrate. In this study various concentrations of agar were taken in a salt bridge like 6gms, 8gms and 10gms and NaOH was also used in salt bridge for the flow of ions. Two different electrode materials like stainless steel rods and copper rods are used to generate electricity. Physiochemical analysis of parameters like TSS, TDS, Alkalinity, Acidity, BOD and COD has been carried out. It was observed that 8 gms of agar concentration with stainless steel rods has been reducing more pollutants when compared to 6gms and 10gms of agar with stainless steel and copper rods and maximum COD removal obtained was 56%.These results demonstrated that Sugar industrial effluent is a suitable substrate in a MFC for bioelectricity production and its treatment. Power output by the salt bridge MFC was 2.2mW/m^2. The low power output was directly attributed to the higher internal resistance of the salt bridge system.

KEYWORDS: Dual Chamber Microbial Fuel Cell, Physiochemical Parameters, Salt Bridge, Steel and Copper Rods.

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1. INTRODUCTION

Rapid industrialization contributes to large quantities of waste water generation, and its treatment is highly imperative. Various technologies for reducing the waste water treatment cost and finding ways to produce useful products from waste water is gaining importance in view of environmental sustainability. By converting chemical energy stored in waste water to electricity, MFC can substantially reduce the operational cost of waste water treatment plants, or even achieve energy self-sufficiency. The electrochemical cell is constructed by using anode and cathode. These anode and cathode are separated by a membrane called salt bridge. Microorganisms oxidize substrates in the anodic chamber to produce electrons and protons. Electrons attached on anode (negative terminal) flow to the cathode (positive terminal) through an external circuit. Protons migrate across the proton/cation exchange membrane to combine with electrons. Around one hundred years ago, the technology of generating electricity through bacteria was found [1-3]. MFCs have many potential applications, such as electricity generation, bio-hydrogen production, wastewater treatment and biosensor [3-5]. Therefore, the number of studies focused on MFCs increased greatly since early 1990s. With the appropriate optimization of architecture or suitable storage of produced energy, microbial fuel cells are able to power a wide range of widely used devices: for example, store the energy in an external storage device (e.g. capacitor) and dispense that energy intermittently in bursts of high-power when needed [6-8] power sensors for environmental parameters monitoring at various time intervals rather than continuously [9], provide power for implantable medical devices placed in human large intestine by utilizing intestinal contents [10], power devices placed on the seafloor or under water environment [11].

Microbial fuel cells (MFCs) are bioelectrochemical devices, a fascinating emerging technology used for the generation of electric current from different complex organic and inorganic sources using living microorganisms as biocatalysts. During the anaerobic

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wastewater treatment process, chemical energy is used for converting waste to H_2, CO_2 and methane. Among them, hydrogen and methane can be used as fuel, but in the microbial fuel cells (MFCs) chemical energy present in the waste components are directly converted to electricity. Exploiting wastewater as a substrate to generate electricity is considered to be a sustainable and promising approach to meet the increasing energy needs and also as a substitute for fossil fuels [12].

Electricity can be produced directly from the degradation of organic matter in a microbial fuel cell [13–15]. Substrates such as swine wastewater, starch processing wastewater, brewery wastewater, and domestic wastewater resulted in low-power density whereas simple substrates such as glucose, acetate has been intensely studied which showed high-power density [16]. In sugar mill industry, a large amount of water is consumed during saccharification process which results in huge wastewater referred as SME. SME has a high content of the organic material and subsequently high biochemical oxygen demand (BOD), particularly because of the presence of sugars and organic material in the beet or cane. Earlier reported typical levels of biochemical oxygen demand (BOD) are 4000– 7000 mg/L in untreated SME while chemical oxygen demand (COD) is up to 10,000 mg/L and the total suspended solids are up to 5000 mg/L. In addition to the sugars and organic materials, SME also contains crop pests, pesticide residues, and pathogens [17]. Electricity production by MFCs has been reported in the literature using carbohydrate-rich wastes such as food processing wastewater, starch processing wastewater and chocolate based wastewater [18]. In this study, sugar mill wastewater was used as the substrate to produce electricity and for wastewater treatment. In this study, the main objectives are construction of the microbial fuel cell and comparative study of different electrode materials like copper rods and stainless steel rods. To optimize the concentration of agar (6gm,8gm,12gm) with a pipe length of 15 cm for high current generation efficiency. Pre and post treatment of water analysis was carried out by determination of Physiochemical analysis of parameters like BOD, COD, Alkalinity, Acidity, and Total dissolved solids (TDS) and Total suspended solids.

2. MATERIALS AND METHODS

2.1 Sample Collection

Sample was collected from sugar industrial waste water and kept in a refrigerator at 4^0C before to use. Standard sample (100% waste concentration) was diluted with distilled water and pH was adjusted in the range from 7 to 7.2 for the adaptation of microbial growth, further 50% sample was taken throughout the study.

2.2 MFC Components

MFC majority constitutes are electrodes, anodic and cathodic chamber and salt bridge as shown in Fig-1.The salt bridge that forms a bridge between cathodic and anodic chamber facilities the transfer of ions (protons). Carbon and steel rods were used as anode and cathode.

2.3 Procedure to Prepare Salt Bridge

Take 150ml of distilled water in a measuring flask and pour it in a pan. Heat it for certain time until bubbles appear. Take 40gms 0f NaOH and pour it in the pan. After NaOH is dissolved take 6gms of agar and pour it in the pan, wait until agar powder gets dissolved. After the agar is dissolved transfer the solution into 15cm PVC pipe with a dia. of 1.8cm, which is closed with a removable cap at the bottom and keep the PVC pipe in a dark place for 24hrs so that the agar solidifies. Repeat the same procedure for 8gms and 10gms of agar.

2.4 Construction of MFC

Two boxes of 1.5 l are taken. A hole of 2 cm dia was made on the opposite sides of both the boxes at the height of 5.5 cm from bottom of box to attach the salt bridge. Agar is already been solidified in the PVC pipe which is used as salt bridge. Attach the PVC pipe containing agar i.e. salt bridge in holes of the boxes with araldite. Leave it for 24 hr to get it dried. Pour same amount i.e. 1.5 l of deionised water (distilled water) and waste water (sugar industry effluent) in respective boxes. The box containing deionised water is the cathodic chamber and the other containing the waste water is the anodic chamber. Copper / Stainless steel rods on which grooves inscribed are used as cathode and anode which are attached at the top of the boxes. Electrical wires are winded in the groves, which are connected to the multi-meter. The setup is run for 12 days. After 12 days of run, the sample of waste water for time period of 48hrs were taken and measured for physicochemical analysis of wastewater.

2.5 Water Quality Analysis

Sample was taken from sugar industry waste water and is treated by Microbial Fuel Cells. In the process, two bottles are taken; one bottle was having waste water sample and the other bottle having distilled water. Copper or Stainless steel rods are dipped into each bottle and a salt bridge was attached between two bottles. After the treatment was done samples were taken to determine Chemical Oxygen Demand. The COD was analyzed using closed reflux method and other parameters like alkalinity, acidity, BOD,TSS and TDS of the raw effluent and the input and output from the MFC were determined according to APHA methods. For regular time intervals of operation of the MFC, The outlet was collected and analyzed for the above mentioned parameters.

2.6 Electrical Measurements

The current (mA) was measured with a digital multimeter connected to the line between the anode and the cathode. The corresponding voltage across the resistor was recorded with time.

3. RESULTS AND DISCUSSION

3.1. Comparative study of current developed at different Agarose Concentrations

The experiments were carried out for copper and stainless steel rods with 6, 8 & 10 gms of agar for a period of 12 days. Figures 2, 3, 4, show the variation of current with respect to time. The current produced in the double chambered MFC's were recorded for a period of 12 days. The mA units of current produced during this period when plotted on a graph followed the pattern of growth curve of the microbial consortia showing an exponential increase for a period of 10 days and reaching the maximum value and remains constant due to decreased levels of electrons produced during the microbial oxidation [19]. This decrease in electrons release is due to decreasing population of microbes as the nutrients gets used up and finally resulting in lower current production. Maximum current of 0.73 mA was obtained for 8 gm of stainless steel rods on the 10th day compared to copper rods. It was observed that there is an increase in current production as the concentration of agarose increases from 6 gm to 8 gm. This is due to effective proton transfer and as the gels is highly polymerized; it prevents the diffusion of oxygen from the cathode chamber to anode chamber through the salt bridge, thus maintaining a better anaerobic environment in the anode chamber encouraging the growth of anaerobic bacteria for increased electrons released [20,21].

3.2. Effect of MFC on various parameters

3.2.1. Effect of MFC on COD

The Chemical Oxygen Demand test (COD) determines, the oxygen required for chemical oxidation of organic matter with the help of strong chemical oxidant. The COD is a test which is used to measure pollution of industrial waste. The waste is measured in terms of equality of oxygen required for oxidation of organic matter to produce CO_2 and water. COD test is useful in pinpointing toxic condition and presence of biological resistant substance. COD of the waste water sample at different time intervals are presented in the Figures 5, 6, 7.When experiment have been carried out for copper and stainless steel rods with 6gms, 8gms and 10gms of agar for 12 days of run, results shows that the maximum COD was reduced from 658 ppm to 286 ppm for 8 gm of agar with stainless steel rods. This decrease in COD indicates bioremediation of the waste supporting the concept of microbes utilizing the organic waste for microbial oxidation. Hence 8 gm of agar with stainless steel rods, the maximum current found was 0.73mA and maximum reduction of COD occurs, hence it was taken as an optimum salt bridge concentration for further studies.

3.2.2. Effect of MFC on Alkalinity

The effect of MFC on Alkalinity of the waste water sample was illustrated in the Fig.8.Sugar industrial effluent treatment and effect of MFC on alkalinity was evaluated by comparing before and after treatment values of waste water parameters. MFC was operated when the experiment has been carried out for stainless steel rods with 8gms of agar for 12 days of run, results shows that alkalinity has decreased from an initial value of 1250 ppm to a final of 875ppm for 8gms of agar with stainless steel rods.

3.2.3. Effect of MFC on Acidity

The effect of MFC on Acidity of the waste water sample was illustrated in Fig. 9.When the experiment has been carried out for stainless steel rods with 8gms of agar for 12 days of run, results show that acidity has decreased from an initial value of 137ppm to a final of 98 ppm for 8gms of agar with stainless steel rods.

3.2.4. Effect of MFC on Total Suspended Solids (TSS)

The Experimental data shows that the amount of TSS in the sample has decreased with the elapse of time. The decrease of the suspended solids in sample may be due to availability of biodegradable substrate in wastewater sample leading to competitive inhibition in microorganisms. Effect of MFC on the removal of TSS of the waste water sample was demonstrated in Fig.10. Results show that TSS of the waste water has decreased from an initial of 2680ppm to 1780 ppm for 8gms of agar with stainless steel rods.

3.2.5. Effect of MFC on Total Dissolved Solids (TDS)

The effect of MFC on total dissolved solids of the waste water sample at regular intervals was presented in the Fig.11. When experiment have been carried out for stainless steel rod with 8gms of agar for 12 days of run, results show that TDS of the waste water has decreased from an initial of 2420 ppm to 1060 ppm for 8gms of agar with stainless steel rods. The decrease in suspended solids in sample may be due to availability of biodegradable substrate in waste water sample leading to competitive inhibition on micro-organisms.

3.2.6. Effect of Biochemical Oxygen Demand (BOD)

Biological oxygen demand is the amount of oxygen required for microbial compounds in water. This demand occurs over some variable period of time depending on temperature, nutrient concentration and the enzymes available to indigenous microbial populations, the amount oxygen required to completely oxidize the organic compounds to Co_2 and water through generations of microbial growth, death, decay and cannibalism. The effect of MFC on BOD of the waste water sample was shown in the Fig. 12. Results show that BOD has decreased from an initial value of 120 ppm to a final of 36 ppm for 8gms of agar with stainless steel rods. However, maximum BOD removal determined in this study was 70% .The decrease in BOD is due to continuous aeration and action of sludge. Table – 1 shows physicochemical properties of Sugar Industry Waste Water before and after treatment for 8gms of Agarose Salt Bridge with stainless steel rods.

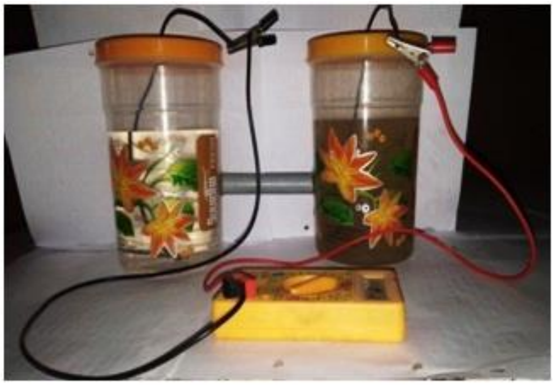

Fig.1 Microbial Fuel Cell for the treatment of waste water

CONCLUSION

The study performed here confirmed the effect of agarose concentration on the performance of the microbial fuel cell as the agarose concentration indicates the permeability of the gel facilitating the transfer of proton. The optimal concentration of agarose for the fabrication of salt bridge was found to be 8% concentration as it showed maximum generation of electricity. Two different types of rods such as stainless steel rods and copper rods are used to generate electricity and to reduce the pollutant levels. When the generation of current is increased the amount of pollutants are decreased. The cell was operated for 12 days in a batch mode. After measuring the water treatment COD, we have obtained that 8gms of Agar with stainless steel rods was reducing the more pollutants when compared to 6gms and 10gms agar with copper and stainless steel rods. However, maximum BOD removal and dissolved solids removal determined in this study were 70% and 90% respectively. The MFC being a promising resource for the future has to be further investigated for improvements in its performance and capabilities to treat waste water with high organic loads.

Table - 1 physicochemical properties of SugarIndustry Waste Water before and after treatment

Parameters	Before treatment (ppm)	After treatment (ppm)
Alkalinity	1250	875
Acidity	137	98
TSS	2680	1780
TDS	2420	1060
BOD	120	36
COD	658	286

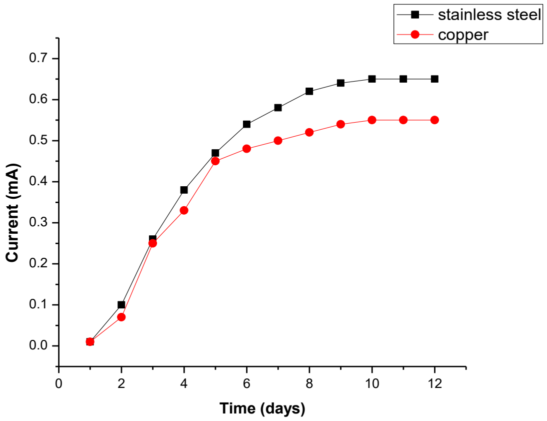

Fig.2 Current Generated with MFC for 6 gms of Agar using Sugar Industry Waste Water

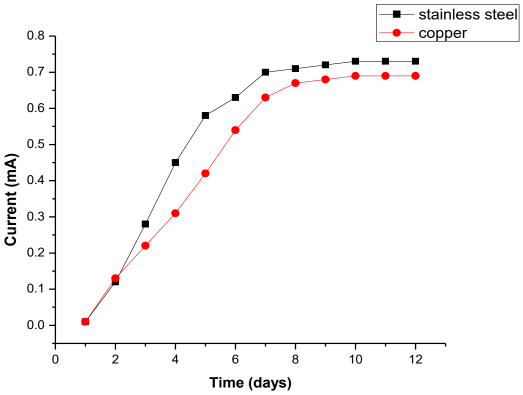

Fig.3 Current generated with MFC for 8gms of Agar using Sugar Industry Waste Water

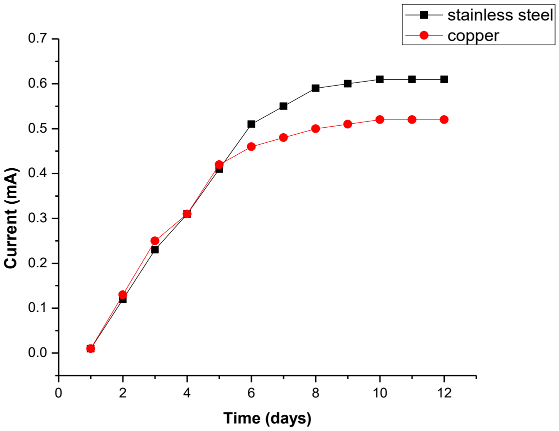

Fig.4 Current generated with MFC for 10 gms of Agar using Sugar Industry Waste Water.

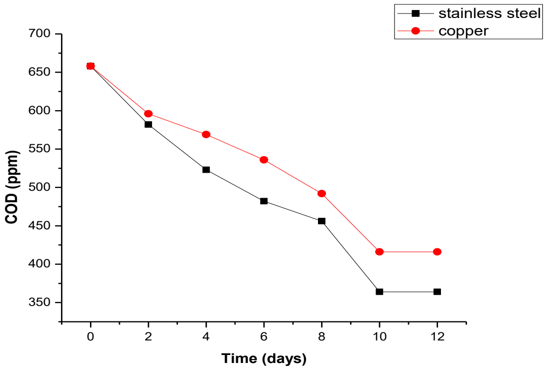

Fig.5 Effect of MFC on COD for 6 gms of Agar using Sugar Industry Waste Water

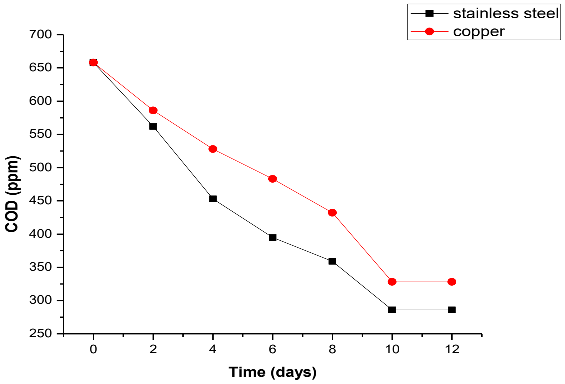

Fig.6 Effect of MFC on COD for 8gms of Agar using Sugar Industry Waste Water

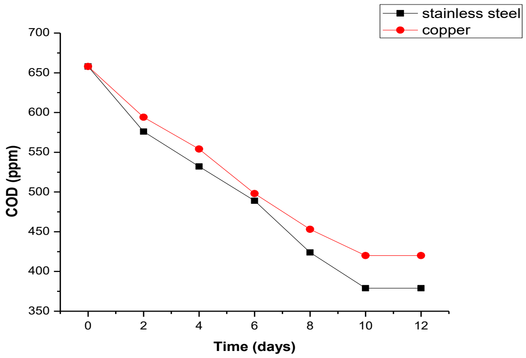

Fig.7 Effect of MFC on COD for 10gms of Agar using Sugar Industry Waste Water

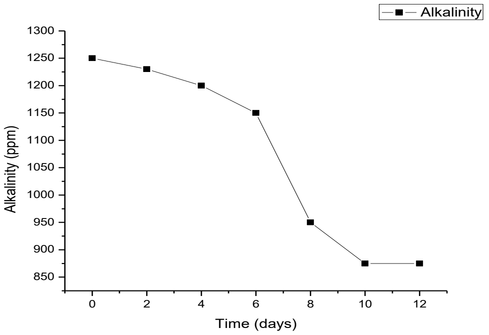

Fig.8 Effect of MFC on Alkalinity for 8gms of Agar using Sugar Industry Waste Water

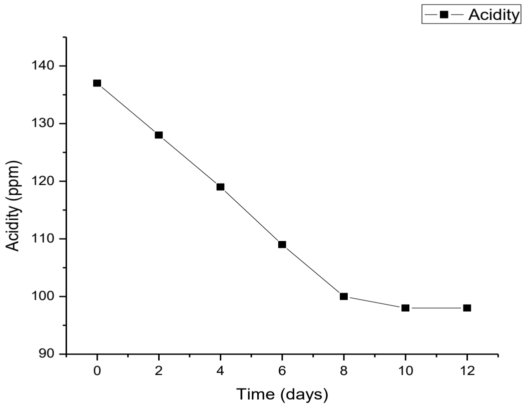

Fig.9 Effect of MFC on Acidity for 8gms of Agar using Sugar Industry Waste Water

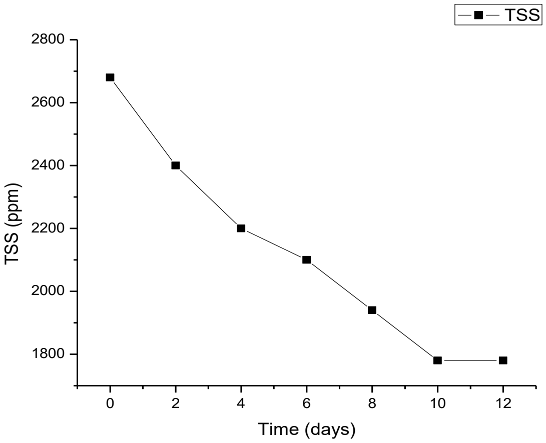

Fig.10 Effect of MFC on TSS for 8gms of Agar using Sugar Industry Waste Water

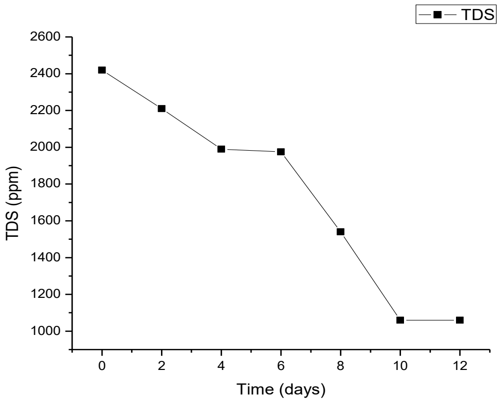

Fig.11 Effect of MFC on TDS for 8gms of Agar using Sugar Industry Waste Water

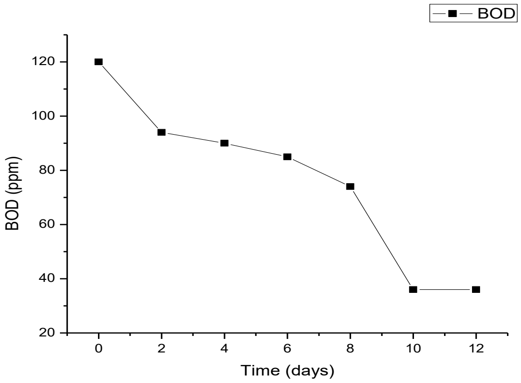

Fig.12 Effect of MFC on BOD for 8gms of Agar using Sugar Industry Waste Water

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